Corn Stover Co-Products

A Course for Commercialization

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Corn Stover
Co-Product Choices

- ***From Biomass to Ethanol Perspective***
  - **Convert cellulose to glucose sugars, and then ferment to ethanol and other products, *$100/ton or more***

OR

  - **Replace hardwood fiber, *$200/ton to $800/ton,* with cellulose pulp from corn fiber**

- ***From Agri-Pulp Perspective***
  - **Burn hemicellulose sugars with lignin**

OR

  - **Remove Fermentation Sugar in Pretreatment**

Corn Stover
Co-Product Revenue

Pro Forma Revenue 1000 DryTons per Day			
Component	EtOH $1/Gal	Mech Pulp $200/ton	90 Bright $800/ton
Cellulose	$18	mix	$70
Other Sugars	$12	mix	$18
Total Revenue	$30	$66	$88

OVERVIEW

- The Past is Prologue
- Process Economics
- Drivers
  - Market Need
  - Producer Benefits
  - Environmental Impact
- Enabling Technologies
- Future Outlook

Past is Prologue

- Non-Wood plants exclusively supplied fiber
- Wood became a factor in 1850's
- Straw and corn stover disappeared in US
  - Combine Harvesting
  - Storage Problems
  - Competition from Wood
- Agri-pulp still important in China and India
- Re-emerging in North America as "tree free"

Process Economics

- Co-Location of Fermentation and Pulp Plants
  - Shared Infrastructure
  - Less Capital
  - Shortened Start-Up Schedule
- Process Confirmation
  - Chemical Usage
  - Enzyme Hydrolysis
  - Product Qualities
  - Energy Required

Process Development

"PRETREATMENT" BALANCE

- Pulp—Fiber Properties
  - Depithing
  - Acid Hydrolysis
- Sugars—Fermentation
  - rFermentation Strain
  - Inhibitors

Market Drivers

- Paper Market Growth
- Producer Benefits
- Environmental Benefits

Paper Growth

- 2000 World Wide Market--300 Million tons
- North America Market--100 Million tons
  - 30% Softwood
  - 30% Hardwood
  - 40% Recycle
- 2010 Market Forecasted to be 400 million tons
- Electronic Office?
  - Office Paper Growth is 20% annually
- Source of Fiber?

Agri-Pulp Fiber Alternative

- Pulp and Paper Industry Perception
  - Does not fit process
  - Weaker fibers
- Corn Stover Fiber
  - Same length as hardwood fiber
  - Coarseness superior to straw
- Agri-Pulp: Replace Hardwood Fibers
  - Supply non-integrated paper market
  - “Tree Free” applications

Grower Benefits

- Remove Excess Stover
  - Reduces
    - -Tillage - Erosion
    - - Pest and Weed Harbor - Chemicals
    - - Phosphate and Potassium
- Soil Moisture Impact
- Replace Nutrients, P & K, as Required
- N Fertilizer is more complex
- Increase Revenue from Sale
- Sequester Carbon from Roots If No-Till

Environmental Benefits

- Improved Residue Management
  - Less Soil Erosion, Chemicals
  - Reduced Water Pollution
    - Groundwater
    - Runoff
- Less Trees to Tissue
- Greenhouse Gas Mitigation

GHG Mitigation from Corn Stover is 12% to 20% of US Kyoto Reduction

(30% of total, 77 million dry tons)

- **US Emissions, MMTCE, 2008-12 . . . 1,740**
- **Kyoto Required Reduction 496**
- **Corns stover Potential, ... 62- 97**
  - Fossil Fuel replacement,
    5.6 to 8 Bil Gal EtOH . . . . . 45 to 64
  - N Fertilizer reduction
    1.6 MM MT N Fertilizer . . . . . 1 to 17
  - Reduced Tillage,
    50% of 32 MM ha Corn
    0.5 M TC/ha/yr 16

Enabling Technologies

- Plant Sciences
  - Fiber Properties
  - Greater Yields
- Collection Cost Reduction
  - More Stover Per Ha (acre)
  - Collection Improvements
- Metabolic Engineering—rFermentation Strains
- Process Improvements
  - Yields
  - Enzymes replace chemicals

CORN STOVER
Largest Biomass Feedstock

Corn Stover, dry tons

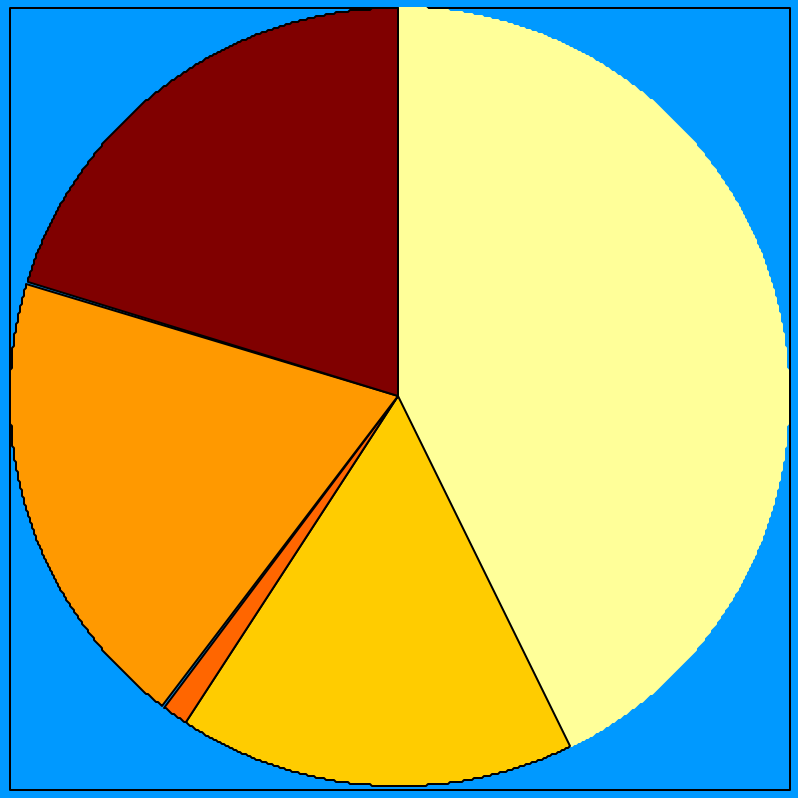
- **255 M tons produced**
- **153 M tons available, 60%**

or 43% of Total Biomass

All less than $50/ton

- **Corn Stover . . . . . 153 M dry tons**
- **Other Ag Stover . . 58**
- **Corn Fiber 4**
- **Energy Crops 70**
- **Wood Co-Products. 72**

TOTAL dry tons . . 357M



IMPACT
Processing 30% of Corn Stover

- **Replaces fiber now supplied from hardwood trees for paper**
- **Adds 5 to 8 billion gallons of Ethanol**
- **$3 Billion Farm Income from Feedstock Sale, $35/dry ton delivered--**
  $10 million per county
- **Mitigates GHGs by 12% - 20% US Kyoto Commitment**

BALE STORAGE
60,000+ Bales in Jan '97